Fast and Accurate Calculation of Thermodynamic Properties in Transient Process Simulations Using a Spline-Based Table Look-Up Method

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The development of modern power cycles requires extensive numerical simulations such as flow analysis with computational fluid dynamics (CFD) and the simulation of transient processes in heat cycle calculation programs. These numerical simulations demand algorithms for fast and accurate calculations of thermodynamic properties. Moreover, thermodynamic properties must be represented continuously and should be numerically consistent to each other. Scientific fundamental equations cannot be used within extensive numerical simulations since the computational effort to evaluate these equations is enormous. In CFD, fluid properties are therefore often calculated using very simple equations, such as the ideal gas equation. Depending on the range of state, this procedure causes inaccuracies in process calculations. A spline-based table look-up method has been developed in this work in order to satisfy the requirements of extensive numerical simulations of modern power cycles and their components. It will be shown that this method is capable of representing thermodynamic properties continuously with high accuracy and high computing speed at the same time. Examples show that in comparison to calculations using fundamental equations, computing speed can be increased by factors of 100-1000 while high accuracy is ensured. Furthermore, complete numerical consistency of forward and backward functions, such as $h(p,T)$ and $T(p,h)$, can be achieved with the proposed approach. The spline-based table look-up method has been applied to several pure fluids and mixtures. Spline-Functions show reasonable behavior and results over the entire fluid range of state, even in the critical region. In order to prove the applicability of the spline-based table look-up method in CFD, practical test calculations have been performed. The broad application of a spline based table look-up method requires a tool for generating the respective tables and functions for a required range of state, and accuracy from a given fundamental equation. Such a tool has been developed within the scope of this project and will also be presented.